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Agricultural Memorandum No 727

The extraction of water from heavy soil under winter sown cereals

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The need to examine the soil moisture profile to arrive at a time for successful field drainage activities (sub-soiling, moling, mini-moling) was discussed in Agricultural Memorandum No 685.

In Agricultural memorandum No 580, a model of water usuage under cereals was constructed, using data from the Rothamsted Report of 1972 and some collected by M R U Cambridge. As these data relate to measurements under spring sown cereals, the ensuing emperical model was adjusted to accommodate winter sown cereals. Further adjustments to the model to take into account the peculiarities of the rewetting of heavy soils are described in Ag. Memo 685.

This updated model was used to estimate the deficits, throughout the growing period, under winter wheat at Drayton. The results were then compared with neutron probe measurement, made at Drayton on three experimental plots; these were made available by the Field Drainage Experimental Unit at Cambridge subsequent to Ag. Mem. No 685 (Fig 1 and appendix I).

Fig 1

	SOIL MOISTURE DEFICIT				
Date	Mean of Neutron Probe Measurements	Model based on Ag. Mem. 580 & 685	% diff	Revised Model	% diff
26/3/74	- 0.7	0.6	-	0	-
22/4/74	27.1	38.2	41	27.1	0
16/5/74	73.1	94.5	29	75.7	4
6/6/74	130.8	153.9	18	134.8	3
18/6/74	151.1	151.6	0	153.7	2
5/7/74	134.5	142.5	6	146.1	9
18/7/74	155.3	160.0	3	165.1	6
2/8/74	177.7	160.0	10	177.0	0
			21	S.D.	5

This comparison shows good agreement in the latter part of the growing season but an over estimation of soil moisture loss in the early part.

Using the Drayton neutron probe measurements, it is possible to build a further model that still retains the broad terms necessary for an areal approach.

Some of the points the Drayton data would seem to suggest are:

i. Water extraction under cereals is restricted to the top 1.5 M; this agrees with Rothamsted and MRU Cambridge data.

ii. Rewetting during heavier rain takes place in all the layers down the profile that have a large deficit (a large deficit is equated with, say, one half of available water in that layer).

iii. Water is extracted simultaneously from several layers at different rates - not progressively downwards as the stores of available water are exhausted.

iv. The available water for cereals grown on heavy soil is greater than that previously suggested (see App. III).

v. That the extra water available is in the top 60 cms.

vi. That the ratio of Actual Evapotranspiration, E, to the Potential Evapotranspiration, E_T, increases steadily during the vegative growth stage of the plant, to reach a maximum of the order of $E=1.5E_T$; this ratio falls sharply at the beginning of the flowering stage; a mean value, between flowering and harvesting is $E=0.75E_T$.

Taking all these points into consideration a suggested model of water extraction by winter cereals, grown in heavy soil, is as follows;

(a) EXTRACTION RATES

Fig 2

Period	E	Available water from
Jan 1 to Apr 15	.75 E_T	0 - 30 cm
Apr 16 " Apr 30	E_T	0 - 60
May 1 " May 31	E_T	0 - 90
Jun 1 " Jun 15	1.5 E_T	0 - 120
Jun 16 " Aug 7	.75 E_T	0 - 150
Aug 8 onwards	E_T	0 - 10

(b) AVAILABLE WATER

Fig 3

Stores	Maximum Available Water	Distribution Ratio to intermediate layers	Intermediate Layers
0 - 30 cm	75 mm	4 3 2	0 - 10 cm 10 - 20 20 - 30
30 - 60 cm	43 mm	8 7 6	30 - 40 40 - 50 50 - 60
60 - 90 cm	35 mm	8 7 6	60 - 70 70 - 80 80 - 90
90 - 120 cm	20 mm	8 7 6	90 - 100 100 - 110 110 - 120
120 - 150 cm	4 mm	3 2 1	120 - 130 130 - 140 140 - 150
Total Water Available	177 mm		

(c) GUIDE LINES

(i) 5 stores of water available (0-30 cm, 30-60 cm etc)

(ii) Water, at the appropriate proportion of E_T, is extracted simultaneously from the top 3 stores (or as many as are available, up to a maximum of three) in the ratio of 4:2:1; that is twice as much water is extracted from the uppermost store as from the one immediately below it.

(iii) Water is returned to the soil as in Ag. Memo 685, except that the return of water to the stores is in the same ratio as it is extracted, ie. any rainfall in excess of 8 mm per day is distributed to all stores that have a deficit greater than 50% of their maximum; an uppermost store receives twice as much as the one below it. Falls of 8 mm or less are accredited to the uppermost store only.

(iv) An estimate of the available water in the intermediate 10 cm layers is arrived at by apportioning the main store content in the ratio given at Fig 3.

(v) Rainfall is returned to the stores on a daily basis where appropriate.

(vi) Evapotranspiration is calculated and extracted on a weekly basis.

(vii) Rainfall is always used at the appropriate rate of E, as indicated in Fig 2.

Using this new model and Drayton's daily rainfall amounts and sunshine records, estimates of soil moisture deficits and profiles in heavy soil under winter wheat were calculated throughout 1974. The comparison of these estimates with the actual Neutron Probe measurements can be seen at Fig 1 and appendix II.

Discussion

(i) The maximum deficit suggested for the total soil moisture profile is of the order 180 mm, and somewhat greater than has been proposed previously. The differences obtained by the neutron probe instrument, between soil moisture at field capacity and the total deficit in the profile around harvest time (on plots drained in different ways) were 193, 181, 160 mm respectively.

The fundamental question remains as to the reservations that should be placed on these figures, a question that stems both from the nature of the measurement and, perhaps more importantly, from its mode of calibration and operation. One would like to see further direct measurements run as a comparison with some alternative and preferably absolute method.

Some help in arriving at a correct modelling of profile deficits could possibly come from a detailed study of drain flow records, after due allowance for wetting down the complete profile under some heavy rains.

Data in MAFF Technical Bulletin No. 16 - Potential Transpiration - show for the drier Eastern counties, an annual average Potential Transpiration of the order 21 inches (525 mm). Even with some allowance for those periods when the crop transpires at a rate greater than the Potential Transpiration rate there are very few areas of the country where the annual average rainfall does not exceed these figures. Within this broad picture, the size of the summer soil moisture deficit is not important (there will always be an overall annual rainfall excess), but the timing of drain flow, when indicative of a return to field capacity, is obviously dependent on the maximum soil moisture deficit.

MAFF Technical Bulletin No 24 - The significance of winter rainfall - uses a model for a shorter rooting crop, grass, for which the maximum soil moisture deficit is 5 inches (125 mm).

If permitted soil moisture deficits are increased to 7-7.5 inches (175-190 mm) then we might possibly infer, by extrapolation of Tables 17, 21, 25 (Bulletin No 24), that after particularly dry summers, the time of return to field capacity might be delayed some 2-4 weeks beyond the latest mean dates shown. This would still imply a return to field capacity in the winter period (January - February) in the East of England. The apparent difficulty thrown up by Table 30 [in which the mean excess winter rain (over winter transpiration) is only of the order 5 inches (125 mm), and the implications seen in this figure for river flow] is resolved if it is recalled that deficits of the order 175-190 mm are only suggested for cereals, on the heaviest land, ie for very limited areas.

(ii) The model of water extracted set down in this memorandum, when applied to data for earlier years at Drayton, does not change the earlier conclusions in any way; the criterion for the failure of secondary drainage operations would remain that the available water in the layer at which the channel is being drawn, should be at, or close to, the water held in the layer at field capacity.

(iii) We may show significant differences in the water content and soil moisture deficits under the different, main and secondary drainage treatments; consequential differences of crop yield are more difficult to determine and the worthwhileness of drainage operations may have to be established on other grounds, for example, on the ease, (cost), possibility and timeliness of soil moving husbandry operations.

Drayton 1971 Winter wheat yields (cwts/acre)

Secondary drainage treatment	Main drainage treatment			
	None	64 m spacing	32 m spacing	16 m spacing
None	34.2	-	31.7	33.5
moling	-	33.2	32.9	35.4
sub-soiling	-	35.1	37.9	34.0

Drayton 1972 Winter beans yields (cwts/acre)

Secondary drainage treatment	Main drainage treatment			
	None	64 m spacing	32 m spacing	16 m spacing
None	30.4	-	29.1	30.4
moling	-	30.4	32.9	33.8
sub-soiling	-	29.6	33.9	32.0

Drayton 1973 Winter wheat yields (cwts/acre)

Secondary drainage treatment	Main drainage treatment			
	None	64 m spacing	32 m spacing	16 m spacing
None	38.6	-	48.8	45.2
moling	-	47.3	47.6	29.4
sub-soiling	-	44.3	37.3 (bg)	49.0

(bg) denotes much blackgrass

Drayton 1974 Winter wheat yields (cwts/acre)

Secondary drainage treatment	Main drainage treatment			
	None	64 m spacing	32 m spacing	16 m spacing
None	14.9 (bg)	-	25.9	20.8 (bg)
moling	-	19.8 (bg)	16.0 (bg)	27.5
sub-soiling	-	30.7	29.6	30.2

Drayton 1974 Moisture content at field capacity and SMD at harvest (bracketed figures) cf appendices I, II, III.

Secondary drainage treatment	Main drainage treatment			
	None	64 m spacing	32 m spacing	16 m spacing
None	-	-	-	755 (160)
moling	-	706 (193)	-	772 (181)
sub-soiling	-	-	-	-

If the total moisture content at field capacity under main drainage treatments is compared, an increase of the order 50-65 mm (2-2.5 ins) is shown as drain spacing is closed; with the crops grown, any associated advantage in crop yield is difficult to demonstrate.

Secondary drainage operations (moling) would appear to increase the water available to the crops grown; in 1974 the deficit under cereals is increased by something of the order 20–35 mm (1–1.5 inches). There is perhaps some associated increase in crop yields over the years with secondary drainage, but this question is not taken further in this paper. Suffice to say that in the UK, cereals are not a particularly water sensitive crop; by the time large deficits are commonly built up, the crop is ready to turn over to its reproductive (and less water demanding) phase of growth.

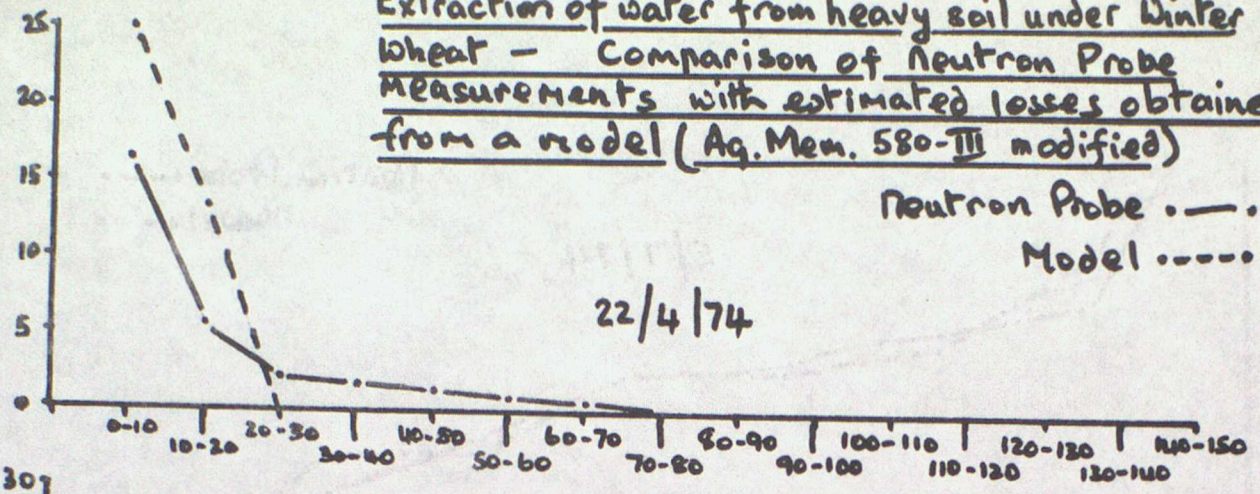
From the very limited data presented above it might be argued that whilst secondary drainage operations apparently increase the water available to crops, and that the size of this increase is of the same order as the increase in total water in the profile (cf. column relating to 16 m spacing), the total water in the profile is primarily a function of the main drainage treatment. Paradoxically, this total water increases as the main drainage is increased (presumably as greater porosity is introduced).

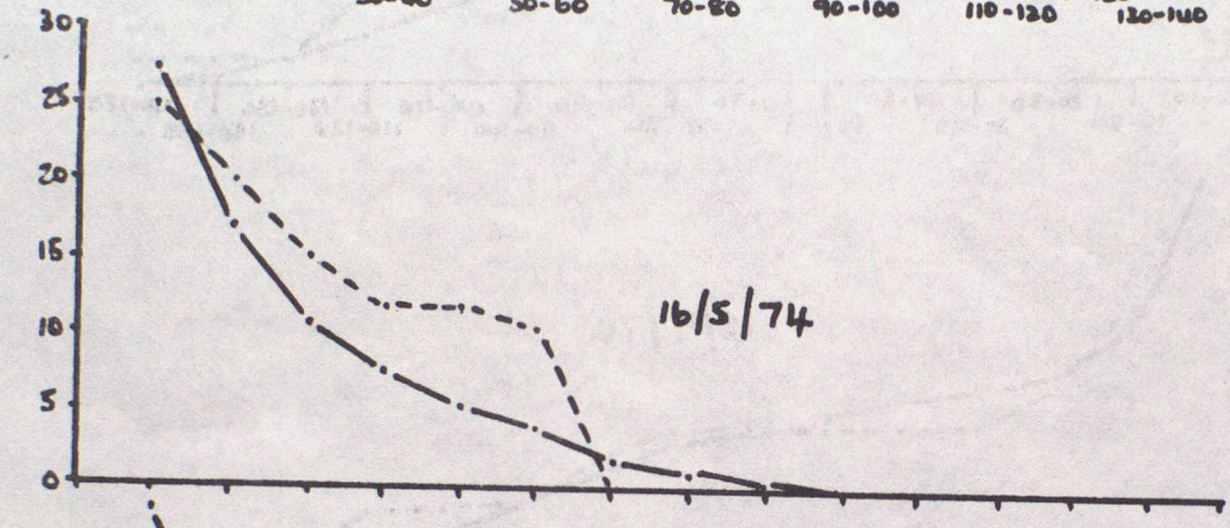
Meteorological Office
Cambridge
March 1975

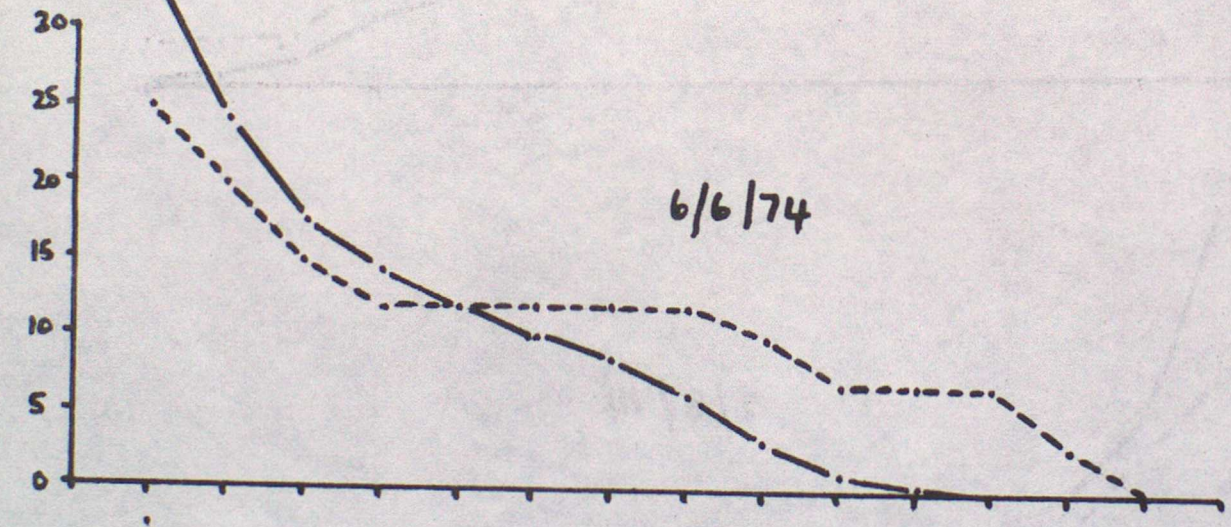
Extraction of water from heavy soil under Winter Wheat – Comparison of Neutron Probe measurements with estimated losses obtained from a model (Ag. Mem. 580-III modified)

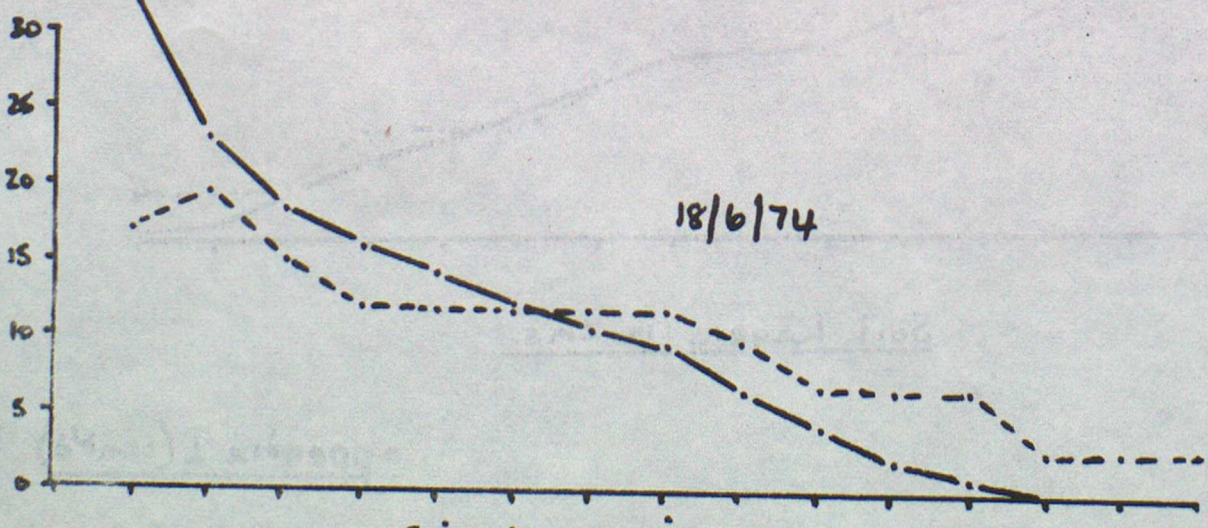
Neutron Probe .—.

Model .- - - -.





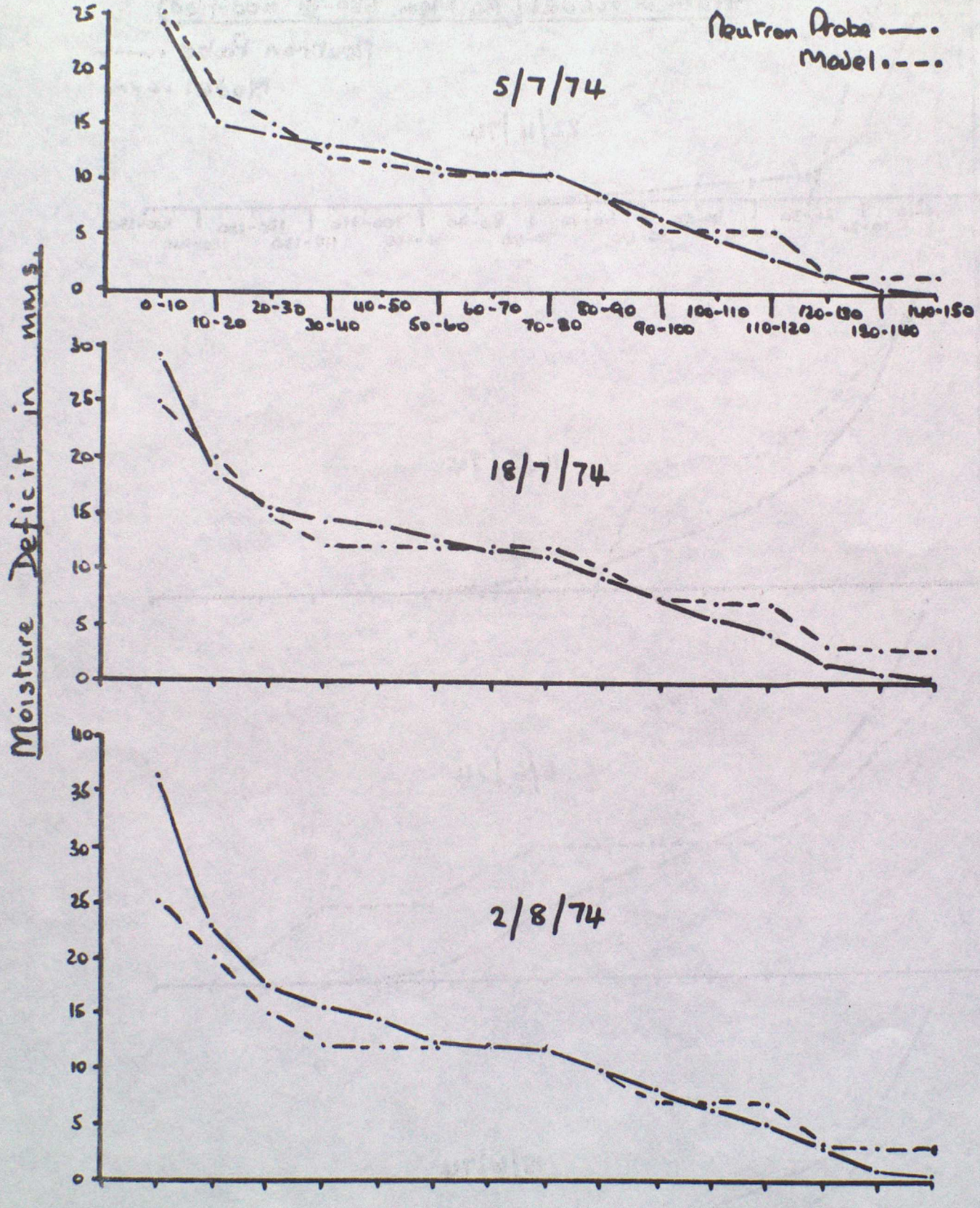




Moisture Deficit in mms.

Soil layers in cms.

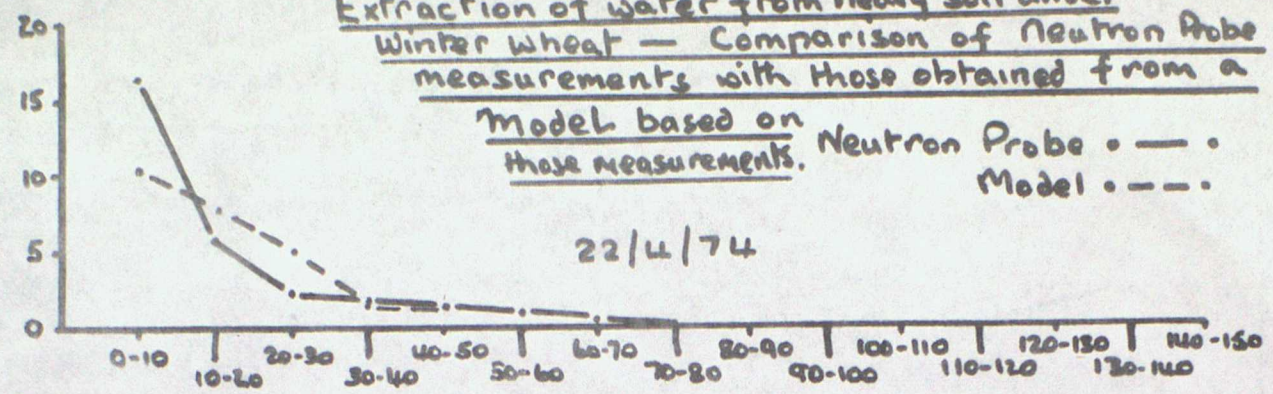
appendix I

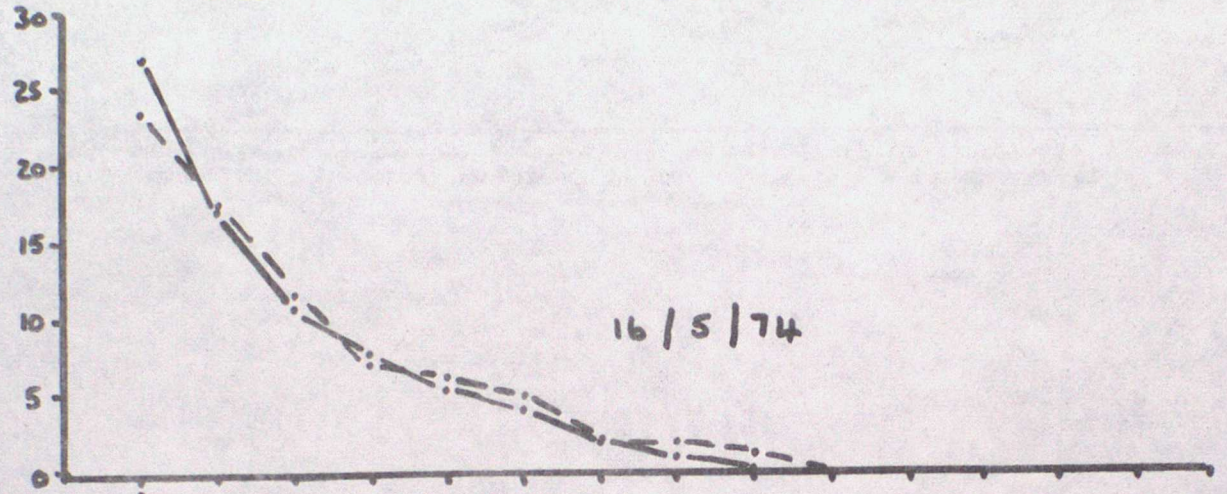


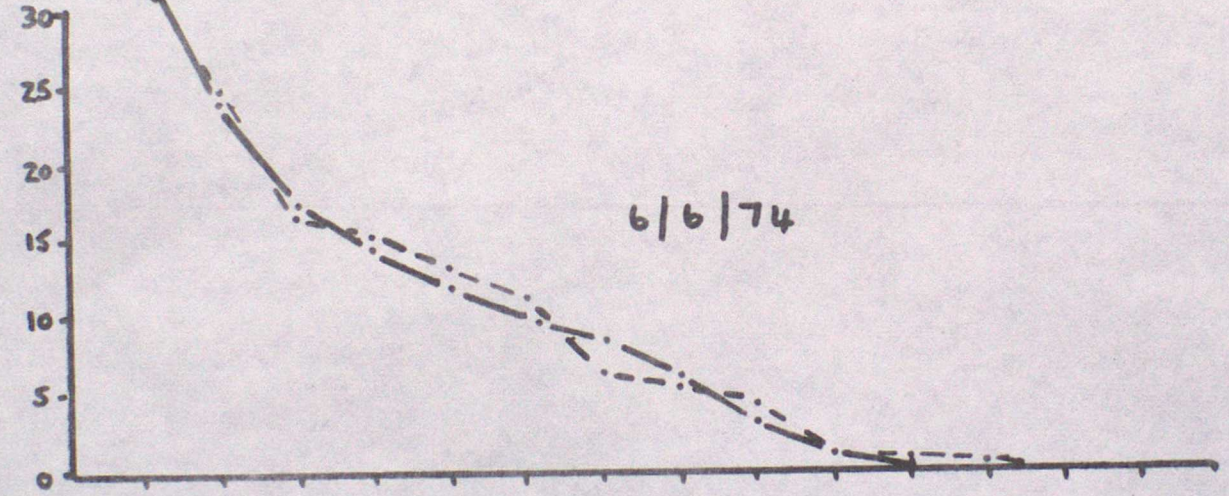
appendix I (cont'd)

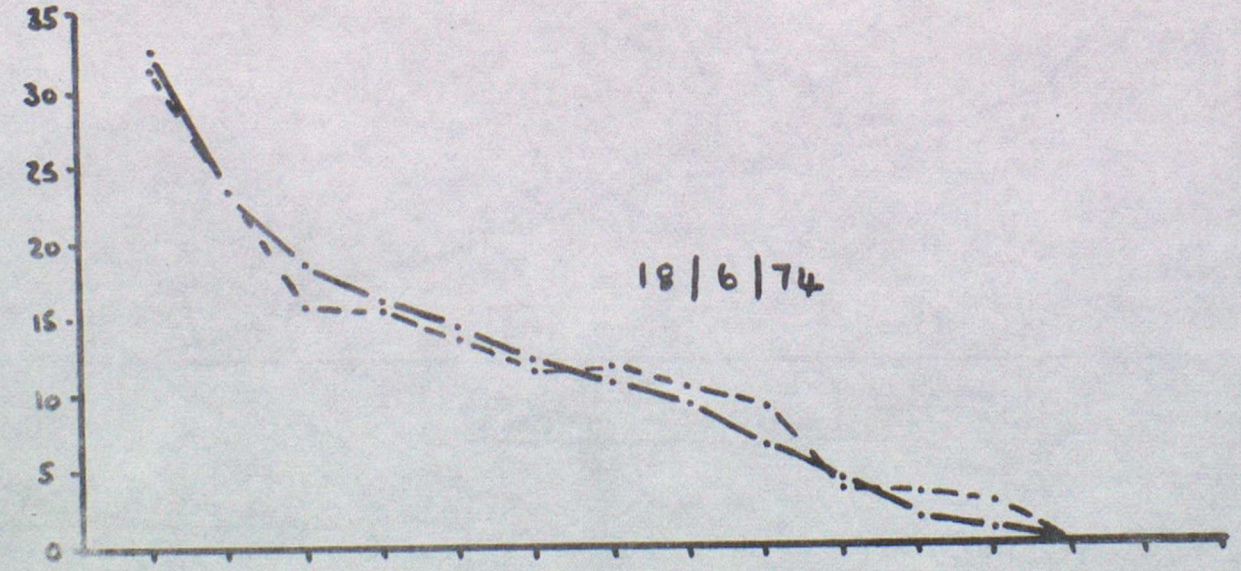
Extraction of water from heavy soil under Winter Wheat — Comparison of Neutron Probe measurements with those obtained from a Model based on those measurements.

Neutron Probe •—•
Model •– –•





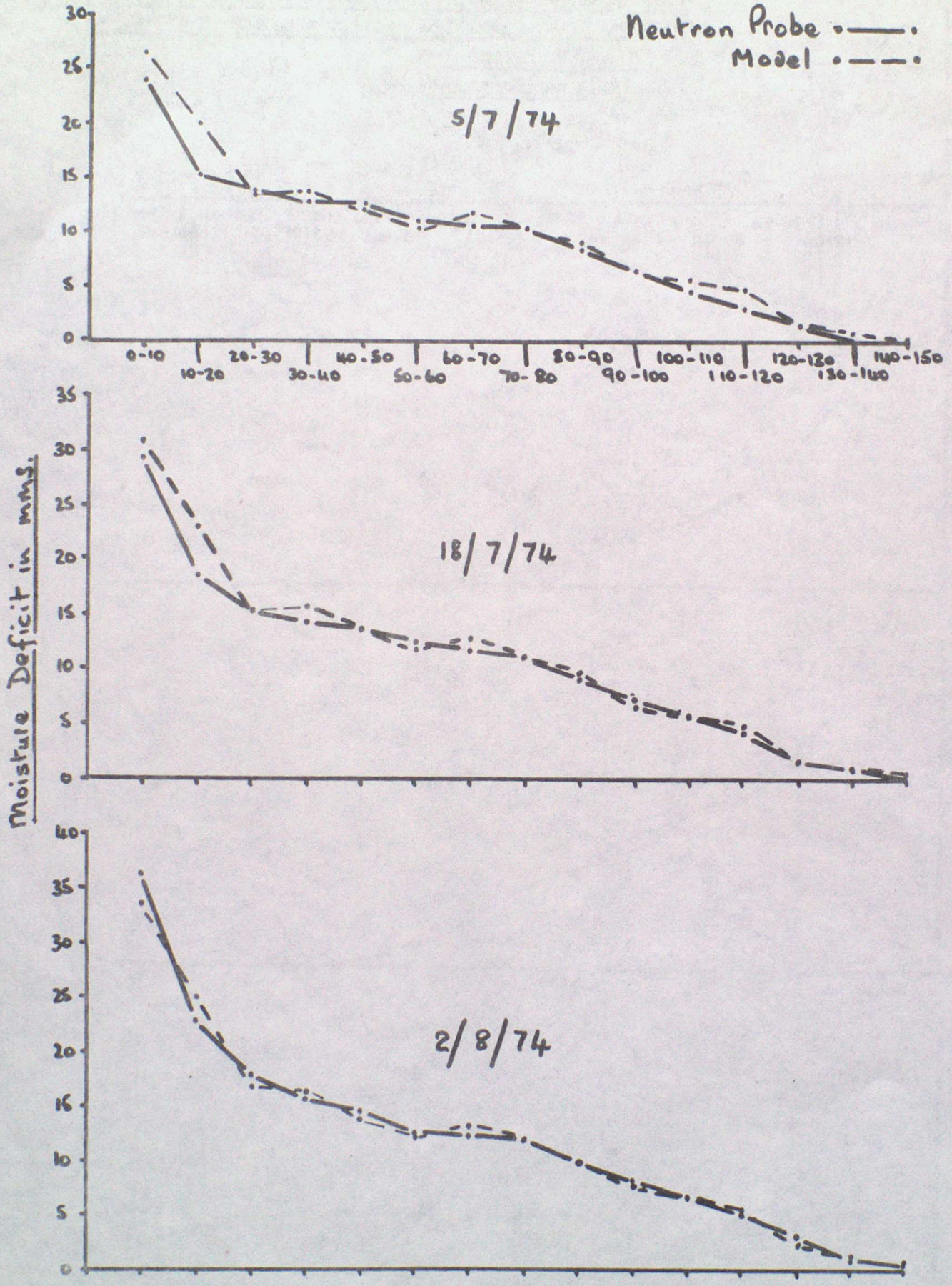




Moisture Deficit in mms.

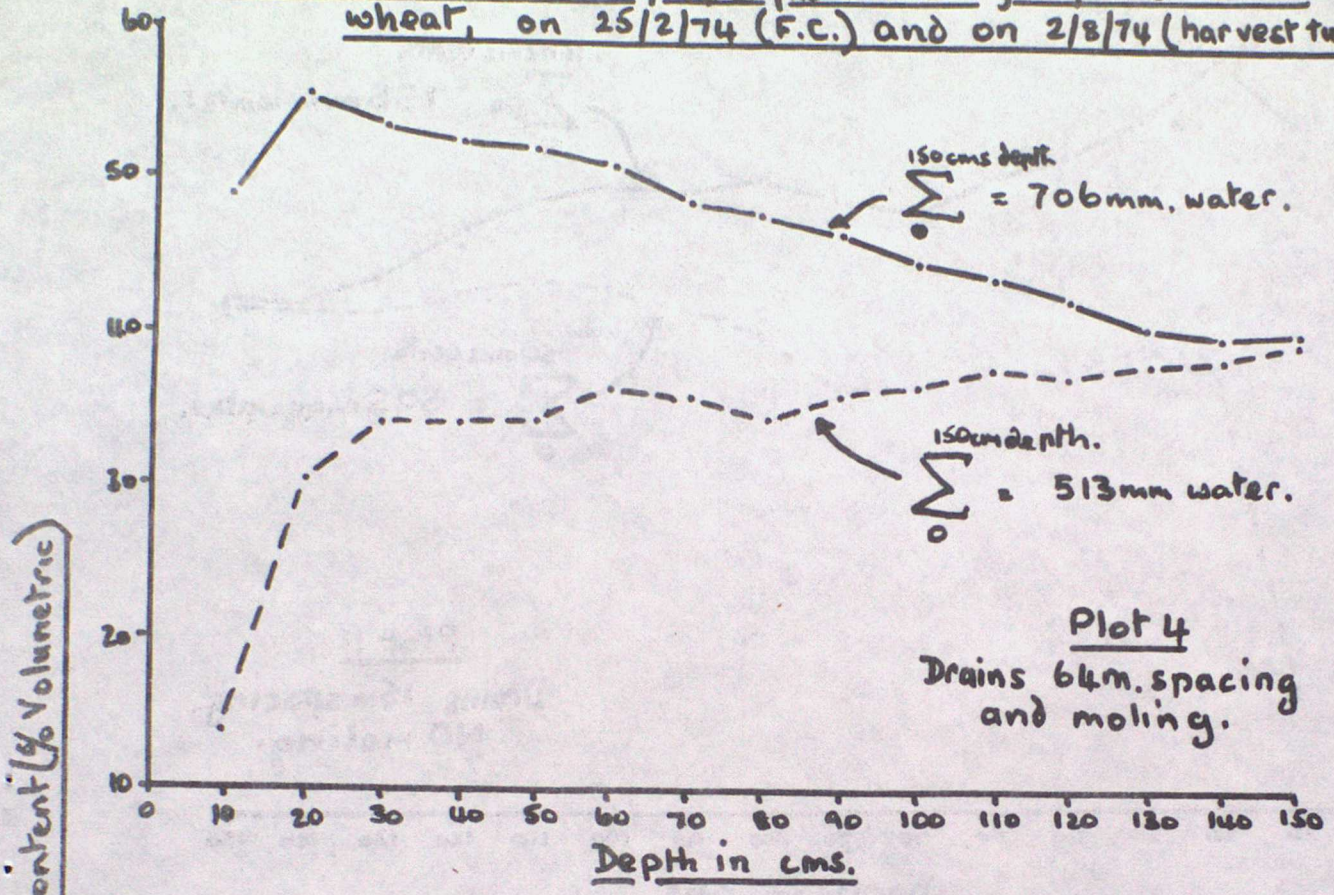
Soil layers in cms.

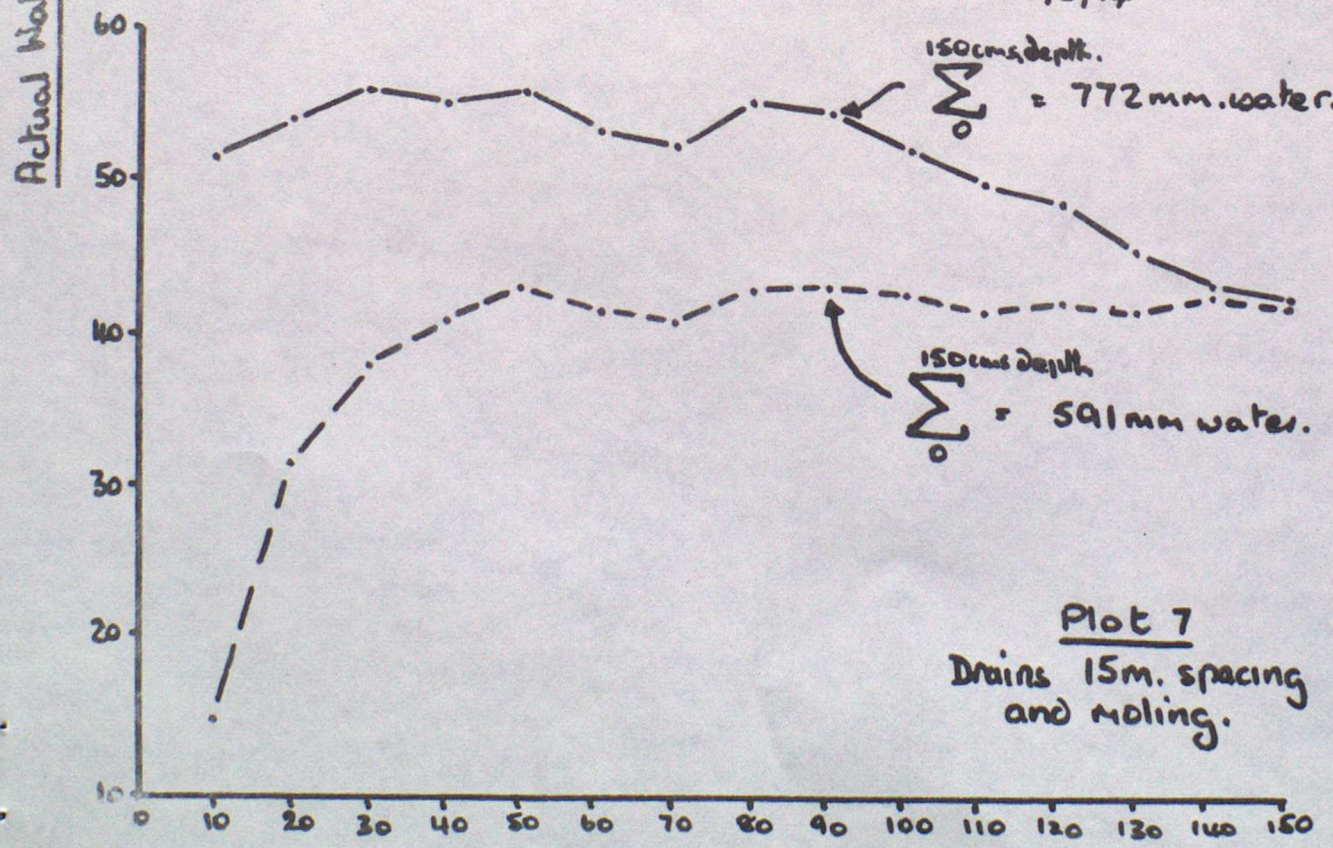
appendix II



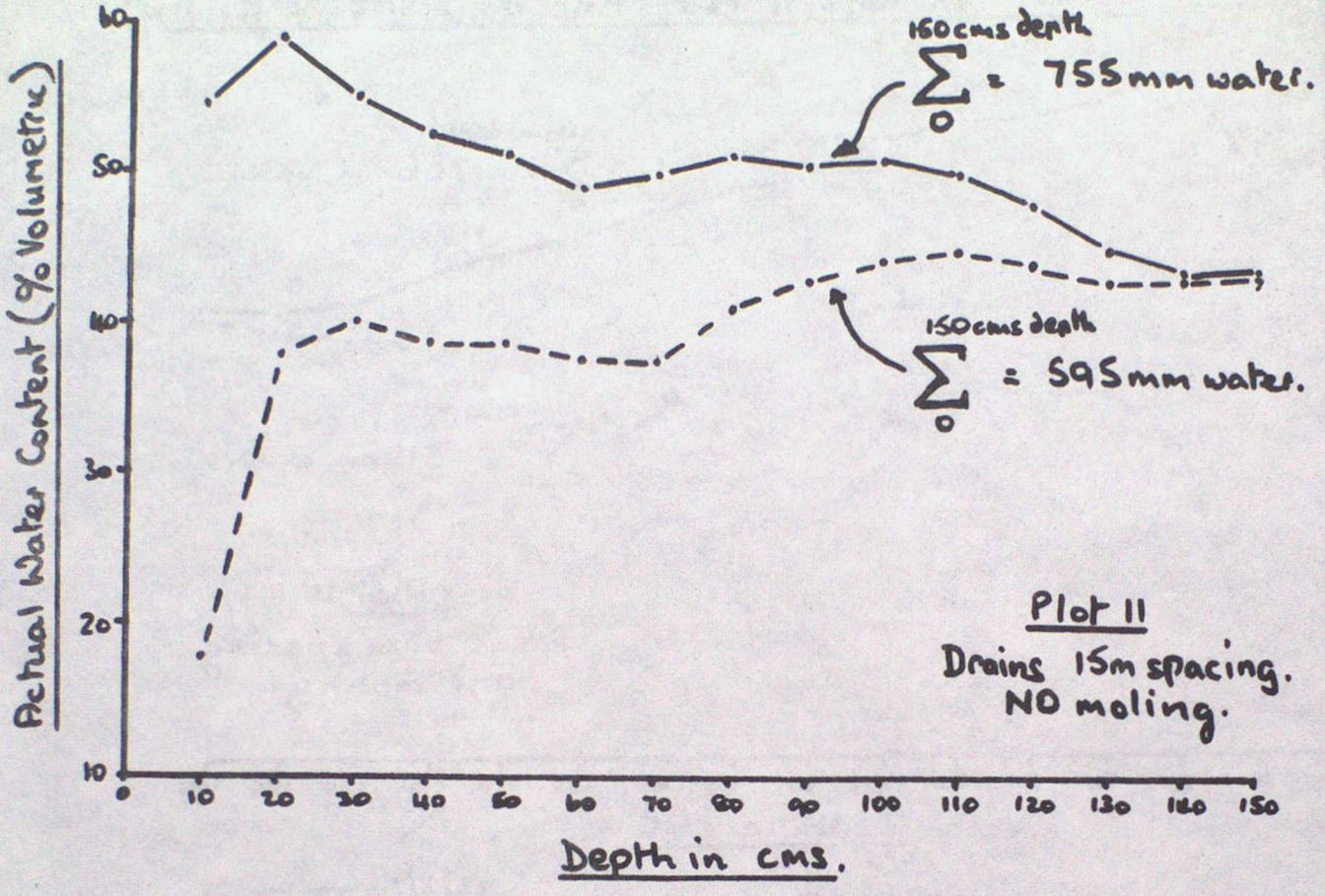
Appendix II (cont'd)

Actual water content of three plots at Drayton, under winter wheat, on 25/2/74 (F.C.) and on 2/8/74 (harvest time).





appendix III



Plot 11

Drains 15m spacing.
NO moling.